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Research Paper

Investigation of the Effect on Tribological Properties of the use of Pinus Brutia Cone as a Binder in Brake Pads

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Abstract

Phenolic resin is invariably used as binder material for friction composites. Alternative materials are considered alternatively to phenolic resin due to negativities such as poor shelf life, harmful volatiles during processing, the need for addition of curing agent before shipment, shrinkage and voids in final products. For these reasons, pinus brutia cones are ground and pulverized and added to the brake lining content at different rates and thus 3 different samples were produced. The wear and friction tests of these samples were made on pin-on disc type brake lining test machine. After this, the density of the samples was determined by using Archimedes scale. The hardness was determined in the Brinell tester. And finally, the microstructure properties of the samples were determined by using a scanning electron microscope (SEM).

Keywords: Pinus brutia cone, brake pad, friction, wear

1. INTRODUCTION

A brake pad is a composite of many different ingredients. Components are classified as fibers, binders, solid lubricants, fillers, abrasives, metallic fillers and friction modifiers. In generally phenolics or their modified versions are used as binder materials for friction composites.

In order for a brake lining to provide safe driving under harsh environment and driving conditions, many features such as regular friction coefficient, low wear rate, thermal deformation resistance and low noise and vibration as comfort conditions are required. Materials such as resin, fiber (fiber), solid lubricant, abrasive particles, metal shavings and fillers are used to provide these desired properties [1].

Storage of various products obtained as waste or leaving them directly to the nature has great negative effects on the society including environmental pollution. Nowadays, scientific studies are carried out for the non-asbestos brake lining [2-8]. There are many studies in the literature to evaluate agricultural wastes. Idris et al. developed a non-asbestos free brake pads using banana peels and results show that banana peels can be used [9]. Koya and Fono produced automotive brake pad using palm kernel shell and the result obtained showed that the palm kernel shell can be used in brake pad [10]. Ruzaidi et al. produced brake pads using palm slag and results showed that palm slag can be used in brake pad composites [11]. Pinus brutia cones are also among the waste products and it is considered as binder due to its resinous structure.

In this study, usage of pinus brutia cone powder as a binder material in brake pad was investigated experimentally.

2. MATERIALS AND METHODS

The friction materials investigated in this work were variations of a NAO (non-asbestos organic) type material containing different ingredients including pinus brutia cone powder. Pinus brutia was obtained from Tarsus/Mersin in Turkey. Three different samples were produced. These samples contained pinus brutia cone powder, phenolic resin, steel fibers, Al_2O_3, Cu particles, graphite, brass particles, cashew and barite. The friction coefficient and temperature values were stored in a databank. The brake lining samples were produced in the conventional procedure for a dry formulation following dry mixing, pre-forming and hot pressing. Detailed conditions for each manufacturing step can be found in the author's other study [12]. The compositions of the friction materials studied in this work are shown in Table 1.

Figure 1 shows a schematic view of the brake tester used in this study. Detailed conditions for each brake test step can be found in the author's other study [12]. The temperature

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and friction-coefficient values were stored in the databank. The tests were repeated three times for each sample. Friction coefficient - temperature - time graphs were obtained to identify the effects of these variables.

Table 1. Ingredients of the samples (weight %)

	KI-0	KI-8	KI-12
Cu particles	8	8	8
Steel fibers	15	15	15
Al_2O_3	5	5	5
Brass particles	5	5	5
Graphite	7	7	7
Barite	30	30	30
Cashew	10	10	10
Pinus brutia cone powder	0	8	12
Phenolic resin	20	12	8

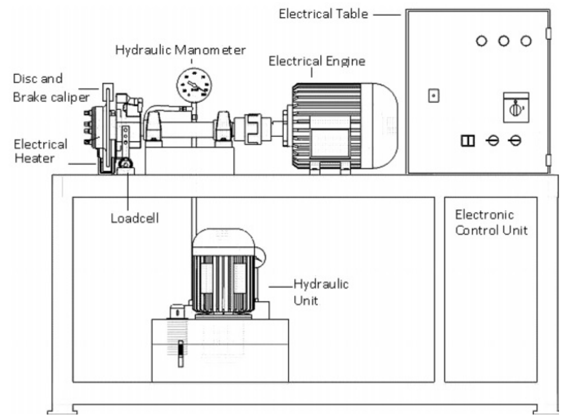

Figure 1. Schematic view of the brake tester

The friction coefficient was calculated by measuring the normal and tangential pressures throughout the test 500 s. It was expressed as the mean value of the entire braking dependence during the friction-coefficient test. The specific wear rate was determined with the mass method following the Turkish Standard [13] and British Standard [14] and calculated with the following Equation (1):

$$V = \frac{1}{2.\pi.R} \cdot \frac{m_1 - m_2}{n.f_s.\rho} \tag{1}$$

where V is the specific wear ratio (cm^3/Nm), R is the distance between the centre of specimen and the centre of the rotating disk (m), n is the rev of the rotating disk (rev/min), m_1 and m_2 are the average weights of specimen before and after the test (g), ρ is the density of the brake lining (g/cm^3), and f_m is the average friction force (N) [12-16].

3. RESULTS AND DISCUSSION

3.1 Effect of the temperature on the friction performance

Based on experimental study results for friction coefficients and temperature graphs are shown in Figures 2-4. Figures 2-4 show time-dependent friction coefficient-temperature graphs of brake pad samples using phenolic resin and pinus brutia cone powder as binder material. The highest coefficient of friction is 0.31 with code KI-8 It is seen in the sample.

Figures 2-4 show temperature changes due to the effect of friction on time. When the shapes were examined, the highest temperature was found at KI-0 and the highest coefficient of friction at KI-8 coded sample.

The friction characteristics after the development of the friction layer were characterized by the characteristics of the constituents of the friction layer in all the samples of the pinus brutia cone powder added. When these graphs showing the variation of the friction coefficient were examined, the KI-0 coded sample showed less fluctuation than the KI-8 and KI-12 coded samples. The increase in the coefficient of friction of the KI-8 and KI-12 coded samples was accompanied by an increase in the internal temperature. This rise in the coefficient of friction can be explained as the ability of the materials constituting the friction layer to improve on the temperature of the disk, which forms the opposing surface of the friction couple, i.e. to create a resistance against the friction surface as the constituent materials are well compatible with each other.

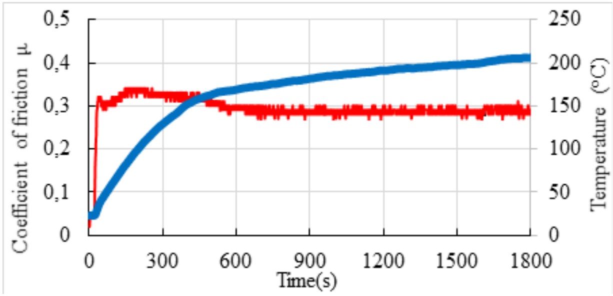

Figure 2. Change in the friction coefficient and the temperature as a function of time for sample KA-0

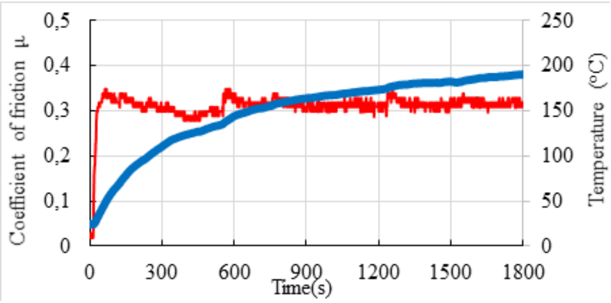

Figure 3. Change in the friction coefficient and the temperature as a function of time for sample KA-8

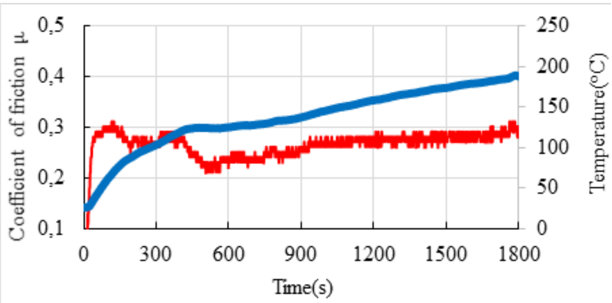

Figure 4. Change in the friction coefficient and the temperature as a function of time for sample KA-12

KI-0 coded specimen decreased in friction coefficient up to 600 seconds. After 600 seconds, the friction coefficient became stable with increasing temperature. The KI-0 coded sample exhibited a low but stable friction with temperature increase.

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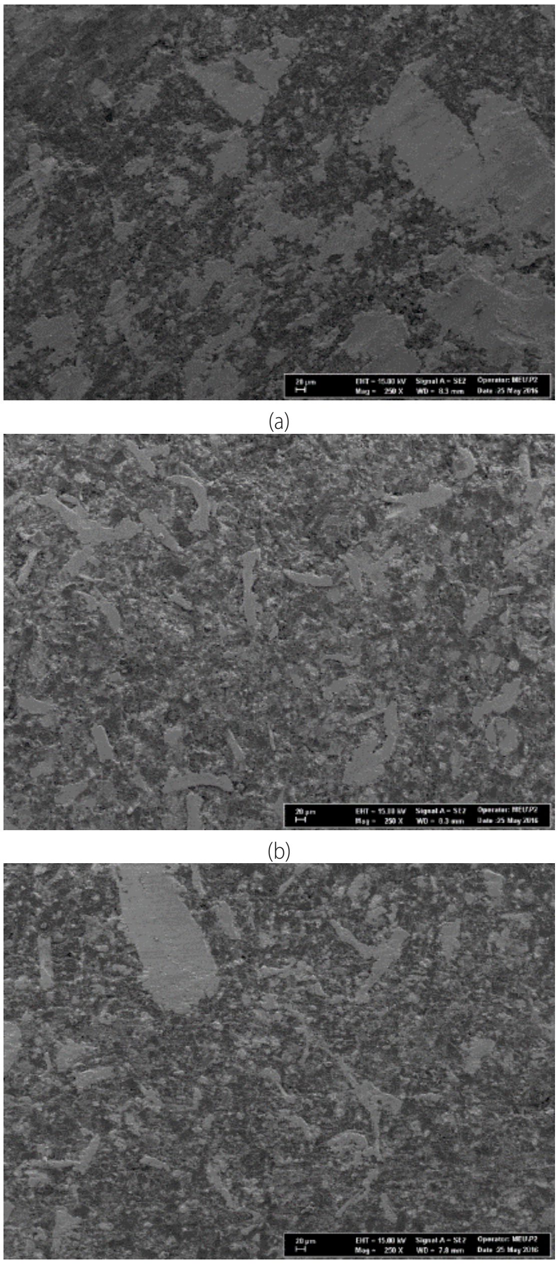
The KI-8 coded sample has gradually increased in the coefficient of friction from the moment it has started to rise above 130 ^{o}C after 400 seconds. The same is true after 500 seconds on the code KI-12. It is thought here that the warmth of the brake pad samples added pinus brutia cone powder causes the development of curing and binder properties. When the graph of KI-0 coded sample was examined, a decrease in coefficient of friction was observed depending on the temperature. When the graphs shown in Figure 3 and Figure 4 are examined, there is an increase in the coefficient of friction depending on the temperature. It is generally emphasized in the literature that the coefficient of friction (μ) varies between 0.1 and 0.7 depending on the frictional force and the disk lining interface temperature [13, 14]. Compared to Figure 2 and Figure 3, the pinus brutia cone powder shows a slight increase in the coefficient of friction of the sample powder sample. Compared to Figures 2 and 4, the frictional performance of the red-brown cone-coated brake pad sample decreases. Comparing the shapes, it is seen that a graph which shows a rise in the coefficient of friction of the pinus brutia powder doped samples as the temperature increases. When the variation coefficient of friction of all samples was examined, the friction in the first 50 seconds showed similar characteristics in surface layer formation as mentioned above. KI-0 coded sample has a partial decrease in temperature from 50th to 500th with an increase in temperature, followed by recuperation. However, a slight increase in the coefficient of friction was observed with increasing temperature after 400 seconds in the sample KI-8 and 500 seconds in the sample the KI-12 code. As shown in Figure 3 and Figure 4, the lowest coefficient of friction is the KI-8 code sample, while the highest coefficient of friction is the KI-12 code.

3.2 Microstructural characterization of friction surfaces

Figure 5 shows the SEM photographs taken to determine the characteristics of the friction surface formed after experiments in which the tribological properties of the pinus brutia cone powder additive brake pads are determined. When looking at photographs in general, it appears that the photographs of the friction surfaces show traces of scratches that show abrasive wear with microfissures, micro-cavities and coated friction layers showing adherent wear. It is also understood that the component-forming materials on the friction surfaces formed actively participate in the friction. 20% by mass of the phenolic resin binder content that KI-0 the SEM photo of the coded sample is shown in Figure 5 (a). This sample exhibited a friction coefficient average of 0.29. The micro voids formed by the particles that are cut from the sample are seen in the picture. Short scratches and color differences on the friction surface indicate that adhesion and abrasive wear have occurred.

In the content of KI-8 coded sample, 12% by mass of phenolic resin and 8% of cornelian cones were observed as a binder, and homogeneous distribution of constituent materials in SEM photograph (Figure 5-b). And the sample exhibited a friction coefficient average of 0.31. Shaped short-sized friction surfaces show abrasive wear. The small clumps that are seen are the result of the barite in the contents. The boundaries of the assembled materials are seen. On the surface of these particles, which are seen as dark and light gray color, it is thought that the materials which are put on these particles after the comeback from other friction regions cause adhesion wear. The white bright colored regions are metal particles that are actively incorporated into the friction.



(a) (b) (c)

Figure 5. SEM micrographs of brake-pad samples (a) KI-0 (b) KI-8 (c) KI-12

Containing 8% phenolic resin and 12% pinus brutia cone powder as binder in order to determine the characteristic of the friction surface of the KI-12 code sample. The SEM photograph taken is shown in Figure 5 (c). In general, it is seen that there are micro-cracks due to thermomechanical stresses and friction coatings formed on the friction surfaces due to short scratches, abrasive wears, micro and macro voids and adherent abrasion resulting from abrasive wear. It is also

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understood that the component-forming materials on the friction surfaces formed actively participate in the friction. The KI-12 coded sample exhibited a coefficient of friction coefficient of 0,26. Component-forming materials may have a hard structure, which may result in high hardness values. However, If the binder of resin holding component-forming materials and general the content orientation is not appropriate, rapid detachment of the component forming particles from the main structure during small stresses during friction can result in high wear rates as expected.

3.3 Wear behaviour

The hardness, density and wear values of the samples are shown in Table 2. When the tables were examined, the coefficient of friction of KI coded samples was 0,28 and the average wear amount was 0,86. In the samples, if the hardness of the brake pad is high, the wear resistance must be high and it can be done as a result. However, If the binder of resin holding component-forming materials and general the content orientation is not appropriate, rapid detachment of the component forming particles from the main structure during small stresses during friction can result in high wear rates as expected.

Table 2. Typical characteristics of the brake pads used in this study

Sample code	Mean coefficient of friction	Density (g/ cm^3)	Brinell Hardness (HB)	**Specific wear rate (cm^3/Nm)** x10^{-6}
KI-0	0,29	2,225	28	1,691
KI-8	0,31	2,300	29	1,997
KI-12	0,26	2,356	26	1,902

4. CONCLUSIONS

In this study, the use of pinus brutia cone powder as a binder in automotive brake pads has been experimentally investigated.

The highest average coefficient of friction value for all specimens undergo friction test is 0.31, belonging to the KI-8-coded specimen containing 8% pinus brutia cone powder, the lowest average friction coefficient is 0.26, belonging to the KI-12 coded specimen containing 12% pinus brutia cone powder. The specific wear rate and density increased with inreasing pinus brutia cone powder for all samples. The experimental results have shown that the friction layer, with the use of pinus brutia cone powder significantly improved the overall performance. With the increasing of temperature, the ingredients in the braking pad were affected other due to faster diffusion. As a result, pinus brutia cone powder can be used as binder for brake pads.

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